STK. # 11630

PRELIMINARY COPY

[redacted]

KEITHLEY INSTRUMENTS, INC.

INSTRUCTION MANUAL

MODELS 414A, 414S

PICOAMMETERS

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has an authorized field repair facility in Los Angeles and in all countries outside the United States having Keithley field representatives.

To insure prompt repair or recalibration service, please contact your local field representative or the plant directly before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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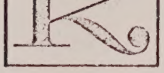

KEITHLEY INSTRUMENTS, INC.

This preliminary Instruction Manual for the Models 414A, 414S is supplied to permit earliest possible delivery of your instrument.

It contains schematics and all the instructions necessary for operating the instrument. The final edition will contain information needed to maintain and calibrate the instrument.

Please detach, fill out and return the Warranty Card attached to the front cover. This card will enable us to send you the final edition by first class mail as soon as it is ready. The final manual can not be shipped if the card is not received.

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SPECIFICATIONS, MODELS 414A, 414S

RANGE: 10^{-10} ampere full scale to 10^{-2} ampere in seventeen 1x and 3x ranges, positive or negative currents.

ACCURACY: ±2% of full scale on 10^{-2} to 10^{-8} ampere ranges; ±4% of full scale on 3×10^{-9} to 10^{-10} ampere ranges.

ZERO DRIFT: Less than 0.5% of full scale per week plus 0.05% per °C on any range after a 10-minute warm-up and with source voltages greater than 1 volt.

INPUT VOLTAGE DROP: Less than 1 millivolt for full-scale meter deflection on any range when properly zeroed.

EFFECTIVE INPUT RESISTANCE: Less than 0.1 ohm on 10^{-2} ampere range, increasing to less than 10^{7} ohms on 10^{-10} ampere range.

RISE TIME, MAXIMUM: Seconds, from 10% to 90%.

Range, ampere	With up to 500 pF Across Input
10^{-10}	0.75
10^{-9}	0.15
10^{-8}	0.13
10^{-7}	0.09
10^{-6}	0.05
10^{-5} and above	less than 0.001

MAXIMUM INPUT OVERLOAD:

Transient: 1000 volts for up to 3 seconds using a Keithley (or other 10 mA limited) High Voltage Supply.

Continuous: 600 volts on 10^{-10} to 10^{-6} ampere ranges, decreasing to 12 volts on the 10^{-2} ampere range.

CURRENT SUPPRESSION: (Model 414S only): Up to 100 times full scale.

Suppression Range: 10^{-9} ampere to 10^{-3} ampere in 7 decade steps, precision 10-turn potentiometer for interpolation between steps. Selectable polarity.

CONNECTORS: Input: Teflon-insulated UHF type. Output: Amphenol 80PC2F.

RECORDER OUTPUT:

Output: ±1 volt or 1 milliampere for full-scale meter deflection. Output polarity is opposite input polarity.

Noise: 414S: Less than 0.3% of full scale peak-to-peak. 414A: Less than 1% of full scale peak-to-peak.

POWER: 105-125 or 210-250 volts (switch selected), 50-60 Hz, 5 watts.

DIMENSIONS, WEIGHT: 5-1/2" high x 8-1/2" wide x 10" deep; net weight, 8 pounds.

ACCESSORIES SUPPLIED: Mating input and output connectors.

SECTION 1. GENERAL DESCRIPTION.

1-1. GENERAL.

a. The Keithley Models 414A and 414S are completely solid-state picoammeters which measure currents over 17 ranges from 10^{-2} to 10^{-10} ampere full scale. Accuracy is ±2% of full scale on the 10^{-2} to 10^{-8} ampere ranges and ±4% of full scale on the 3×10^{-9} to 10^{-10} ampere ranges.

b. The Picoammeters employ matched IG FET transistors in the input followed by a differential amplifier stage, a transistor driver and a transistor output stage. Negative feedback is used for stability and accuracy.

1-2. FEATURES.

a. The time and temperature stability of the 414A and 414S Picoammeters is unmatched by any other inexpensive picoammeter. The Models 414A and 414S will operate for days without requiring rezeroing. Zero drift with time is less than 0.5% of full scale per week. Temperature drift is equally small — a change of 10°C affects the reading less than 0.5% of full scale on the most sensitive range.

b. A unique circuit provides complete overload protection for Models 414A and 414S without compromising the outstanding features of the IG FET input. The Picoammeters will withstand transient overloads up to 1000 volts without damage, and overload recovery is almost instantaneous.

c. Fast warm-up is an inherent characteristic of the Picoammeter. It can be used almost immediately on its most sensitive range. For maximum stability, however, about 10 minutes warm up time should be allowed.

d. Many features accent user convenience. Only two operating controls are needed for the Model 414A: the Range selection switch and the Meter Switch. The Meter switch turns the instrument on, sets the polarity and checks zero. The 4-1/2-inch taut band meter with mirror-backed scales is rugged, easy to read and provides excellent resolution.

e. One volt or 1 milliampere at full-scale deflection on all ranges is provided to drive chart recorders. The 1 milliampere recorder output will drive the Keithley 370 Recorder directly. When potentiometric recorders are used, the output voltage can be conveniently divided by a shunt resistor and adjusted for full scale with the rear panel Calibration potentiometer.

1-3. DIFFERENCES BETWEEN THE MODELS 414A AND 414S.

a. The Picoammeter circuits in the two models are the same. The Model 414S, however, provides a suppression current at the input up to 100 times full scale on most ranges. This permits full-scale display of 1% variations of a signal or suppression of a steady background signal.

b. The instructions in this Manual are for both models, except those paragraphs concerning suppression current operation and circuit. These instructions are identified as applying only to the Model 414S. Separate schematic diagrams are contained in the Manual for each instrument.

TABLE 2. Models 414A, 414S Front Panel Controls (Figures 1 and 2).

Control	Functional Description	Par.
RANGE Switch	Selects full-scale current range instrument is to measure.	
METER Switch	Turns instrument on; selects meter polarity; checks instrument zero.	
ZERO ADJ. Switch	Zeroes meter on any range.	
Pilot Light	Glows to indicate instrument is on.	
SUPPRESSION, MAX AMPERES Switch (414S only)	Selects suppression current magnitude and turns suppression current off.	
SUPPRESSION, FINE and Polarity Switch (414S only)	Concentric switches: one determines polarity of suppression current, the other (FINE) interpolates between settings of the MAX AMPERES Switch.	

TABLE 3. Models 414A, 414S Rear Panel Controls (Figure 3).

Control	Functional Description	Par.
INPUT Receptacle	Connects input to source. Receptacle is a Teflon insulated UHF connector.	
OUTPUT Receptacle	Connects output to monitoring device.	
1 MA — 1 V Switch	Selects output of instrument: 1 milliampere or 1 volt.	
1 MA CAL Control	Adjusts output from 0.95 to 1.05 ma.	
117-234 Switch	Sets instrument for 117 or 234 volt ac power line.	
Fuse	3AG Slow-Blow. 117 volt - .125 amp; 234 volt - .062 amp.	

SECTION 2. OPERATION.

2-1. INPUT CONNECTIONS. Use the following precautions when using the Picoammeter on the more sensitive ranges. These precautions need not necessarily be followed if measurements are to be made only on the less sensitive ranges.

a. The INPUT Receptacle of the Models 414A and 414S is a Teflon-insulated UHF connector. The Center terminal is the high impedance terminal, and the outer shield is case ground.

b. Carefully shield the input connection and the current source being measured, since power line frequencies are well within the pass band of the Picoammeter on all ranges. Unless the shielding is thorough, pickup may cause definite meter disturbances.

c. Use high resistance, low-loss materials — such as polyethylene, polystyrene or Teflon — for insulation. The insulation resistance of test leads and fixtures should be several orders of magnitude higher than the source resistance. Excessive leakage will reduce accuracy. Any coaxial cable used should be a low-noise type which employs a graphite coating between the dielectric and the surrounding shield braid.

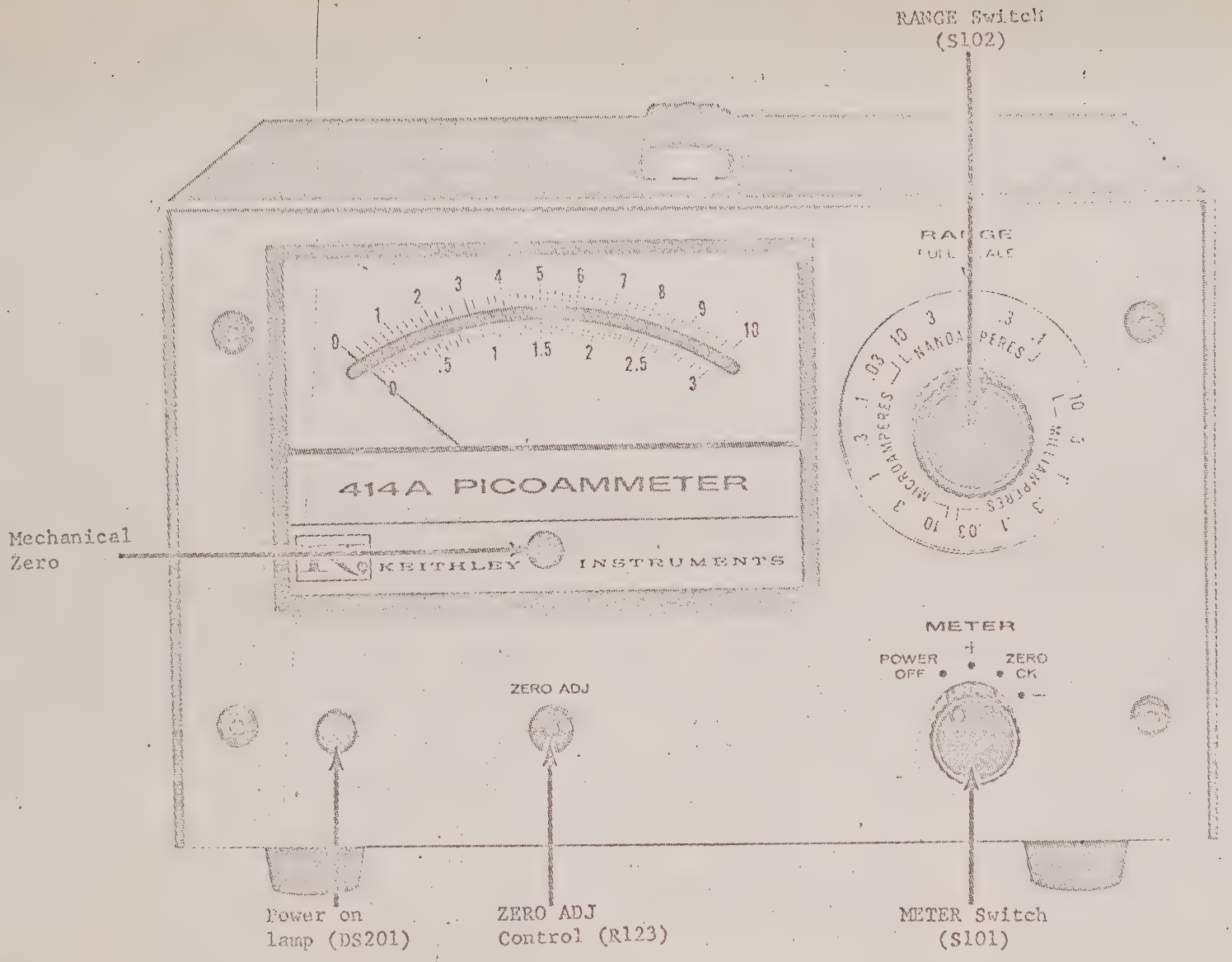
d. Any change in the capacitance of the measuring circuit to ground will cause disturbances in the reading, especially on the more sensitive ranges. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. If a continuous vibration is present, it may appear at the output as a sinusoidal signal and other precautions may be necessary to isolate the instrument and and the connecting cable from the vibration.

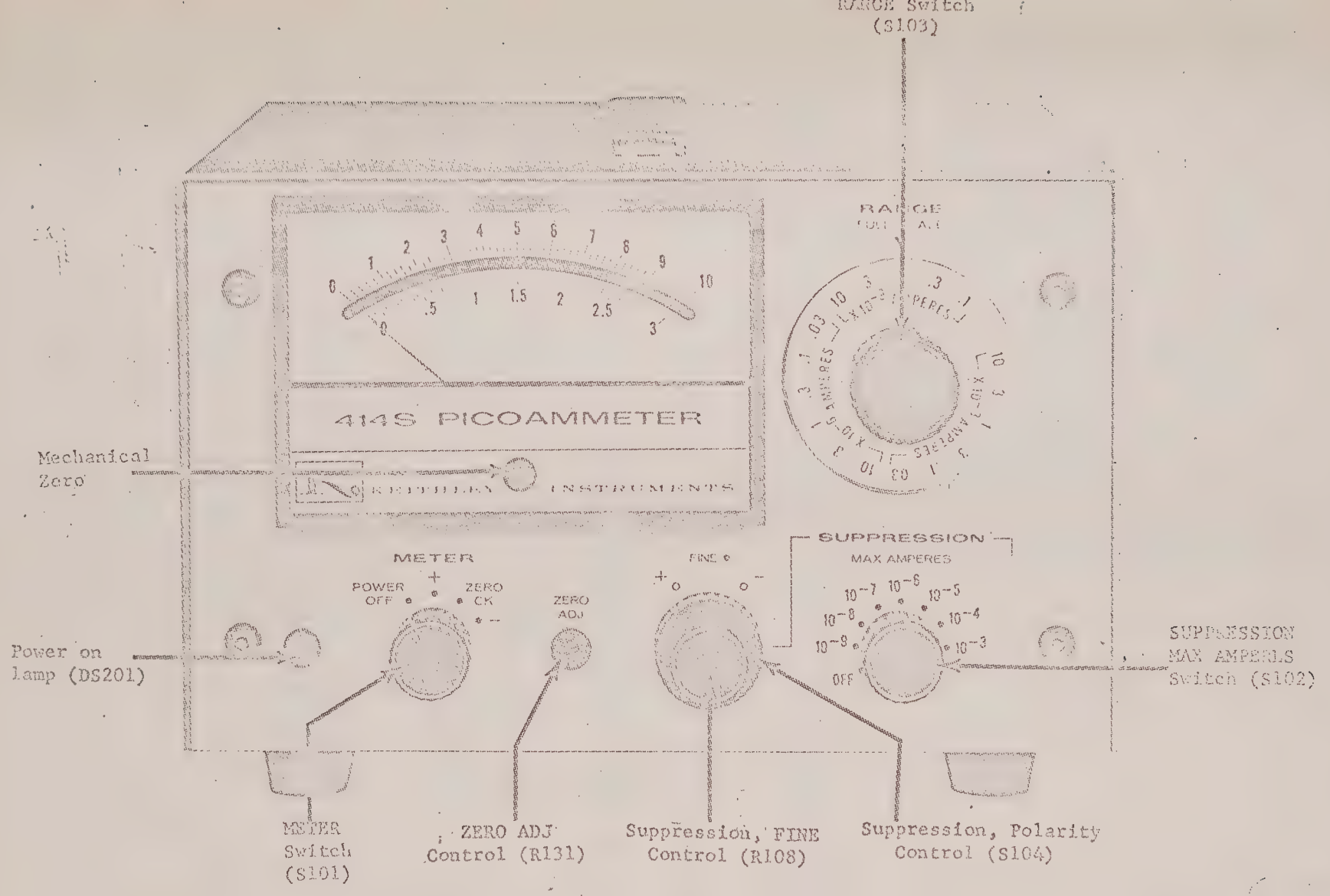
NOTE

Keep the shield cap on the INPUT Receptacle when the Picoammeter is not in a circuit.

FIGURE 1. Model 414A Front Panel Controls.

FIGURE 2. Model 414S Front Panel Controls.


RANGE Switch
(S102)
414A PICOAMMETER
KEITHLEY INSTRUMENTS
METER
POWER
OFF
ZERO
CK
ZERO ADJ
Mechanical
Zero
Power on
lamp (DS201)
ZERO ADJ
Control (R123)
METER Switch
(S101)


RANGE Switch (S103)
414S PICOAMMETER
KEITHLEY INSTRUMENTS
Mechanical Zero
METER
POWER OFF
ZERO CK
ZERO ADJ
FINE
SUPPRESSION
MAX AMPERES
OFF
Power on lamp (DS201)
SUPPRESSION MAX AMPERES Switch (S102)
METER Switch (S101)
ZERO ADJ Control (R131)
Suppression, FINE Control (R108)
Suppression, Polarity Control (S104)

2-2. OPERATING PROCEDURES.

a. Check the fuse and the 117-234 volt switch for the proper line voltage.

b. Connect the power cord to the power source.

c. Set the RANGE Switch to 10^{-2} amperes and the METER Switch to (+). Within seconds the meter needle should read zero. Zero the meter with the ZERO ADJ Control. After a few moments increase the current sensitivity by advancing the RANGE Switch in decade steps to the 10^{-10} ampere range. Continue zeroing with the ZERO ADJ Control. The instrument is now ready to use.

NOTE

For the Model 414S only, make sure the SUPPRESSION, MAX AMPERES Switch is set to OFF. If the Switch is in any other position, a suppression current can be introduced, causing error in measurement.

FIGURE 3. Models 414A, 414S Rear Panel Controls. Rear panel is same for both models.

d. If long term measurements are to be made, allow the instrument to warm up for at least 10 minutes.

e. Attach the current source and turn the METER Switch to the polarity of the input signal, + or -. Increase sensitivity with the RANGE Switch until the greatest on scale deflection is achieved.

1. When the RANGE Switch is set to 10, 1, 0.1, etc. positions, use the upper meter scale. Full scale current range is equal to the RANGE Switch setting.

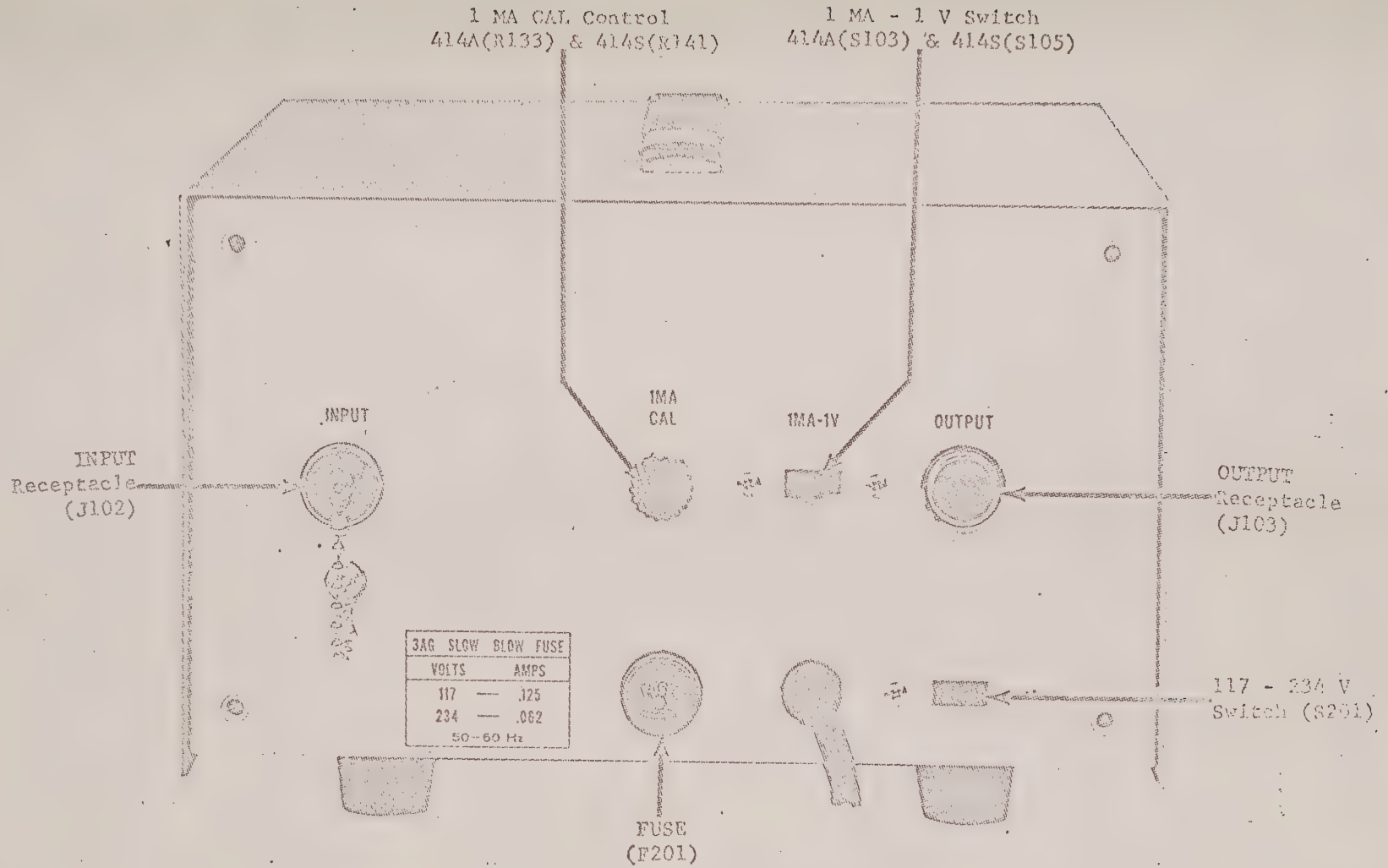
2. When the RANGE Switch is set to 3, 0.3, 0.03, etc., positions, use the lower meter scale. Full scale current range is equal to the RANGE Switch setting.

2-3. MEASUREMENT CONSIDERATIONS.

a. The Picoammeter employs the fast method of current measurement — the measuring resistor is between the amplifier input and output in the feedback loop. This method largely neutralizes the effect of input capacity and greatly increases the response speed. Also, the input voltage drop is reduced to a maximum of one millivolt on any range.

b. Rise time varies with the current range and the input capacity (see specification, Table 1). The rise time, though, is not affected with up to 500 picofarads across the input; however, it is better to place the Picoammeter nearer the current source than to the data reading instrument. Transmitting the input signal through long cables — with greater than 500 picofarads of capacitance — will increase response time and meter noise.

c. The internal resistance of the unknown source should not be less than the reciprocal of the current range being used, otherwise the zero stability will be affected. The


1 MA CAL Control
414A(R133) & 414S(R141)
1 MA - 1 V Switch
414A(S103) & 414S(S105)
INPUT
IMA CAL
IMA-1V
OUTPUT
INPUT Receptacle (J102)
OUTPUT Receptacle (J103)
3AG SLOW BLOW FUSE
VOLTS AMPS
117 — .125
234 — .062
50-60 Hz
117 - 234 V Switch (S201)
FUSE (F201)

instrument will still be operable, however, but the sensitivity will be approximately

$$R_f/R_s \qquad \text{equation 1.}$$

where R_f is the feedback resistance in ohms;
and R_s is the source resistance in ohms.

For example, if the source to be measured has a resistance of 10^5 ohms and the current is 10^{-6} then the feedback resistor will be 10^6 ohms. This means that the gain of the Picoammeter is $10^6/10^5 = 10$. Then the zero stability of .5%/week will be .5% X 10 = 5%/week, and the offset due to temperature will be 0.5% X 10 = .5%/°C. This is the reason that it is advantageous to have the source resistance at least equal to the feedback resistor.

d. Overload Protection. A unique circuit provides complete overload protection for both the Models 414A and 414S without compromising the features of the MOS FET input. Overload recovery is almost instantaneous.

1. At the 10^{-6} ampere range and below the Picoammeter can withstand overloads of up to 1000 volts for 3 seconds and continuous overloads of up to 600 volts without damage.

TABLE 4.
Allowable Overloads on Ranges Above 10^{-6} amperes.

Range	Max. Continuous Voltage Overload	Max. Continuous Current Overload
10^{-5}A	300 v	1 ma
10^{-4}A	120 v	4 ma
10^{-3}A	30 v	10 ma
10^{-2}A	12 v	40 ma

2. For ranges above 10^{-6} ampere, the maximum continuous overload is restricted due to the power dissipation of the feedback resistors (See Table 4).

3. For maximum protection, use a Keithley Model 240A Voltage Supply or some other 10 milliampere current limited supply in combination with the Picoammeter.

2-4. SUPPRESSION CURRENT OPERATION (Model 414S). These instructions apply to the Model 414S only. The Model 414S provides up to 100 times current suppression over a range of 10^{-3} to 10^{-9} ampere. By suppressing background currents, variations as small as 1% in a larger signal can be displayed full scale. Currents of either polarity may be suppressed.

a. Set the SUPPRESSION, Polarity Control to + or -, as necessary.

b. Set the SUPPRESSION, MAX AMPERES Switch to the same sensitivity as the RANGE Switch setting. Adjust the 10-turn FINE Control for a zero reading on the meter. Increase the sensitivity of the RANGE Switch one decade. Adjust the FINE Control for a zero reading. This is ten times current suppression. To obtain 100 times suppression, increase the sensitivity of the RANGE Switch one more decade and zero the meter. In this mode the Model 414S is able to detect fluctuations of 1% of full scale of the suppression current.

2-5. RECORDER OUTPUTS.

a. For recording with the Models 414A and 414S, use the Keithley Model 370 Recorder for ease, economy, versatility and performance. The Model 370 is a pen recorder with 10 chart speeds and 1% linearity. The Model 370's input cable has a connector which mates directly with the OUTPUT Connector on the Picoammeter; this avoids interface problems often encountered between a measuring instrument and a recorder. The Picoammeter output, when set to the 1 MA position, will drive the 370; no preamplifier is needed. No special wiring is required.

b. Other recorders, oscilloscopes and similar instruments can be used with the Models 414A and 414S. The Picoammeter has two outputs, ±1 volt and ±1 milliampere, to amplify signals for recorders, oscilloscopes, and similar instruments. These can be used on all ranges of either Model.

c. 1-Volt Output. Connect oscilloscopes and pen recorder amplifiers to the OUTPUT Receptacle. Pin no. 1 is the high terminal and pin no. 2 is ground. Set the 1 MA - 1V Switch to 1V. The Picoammeter output is now ±1 volt for full-scale meter deflection on any range. Internal resistance is approximately 1 kilohm. Noise is less than 1% (414A) and 0.3% (414S) peak-to-peak of full scale. The METER Switch does not reverse the output polarity. Output polarity is always opposite input polarity.

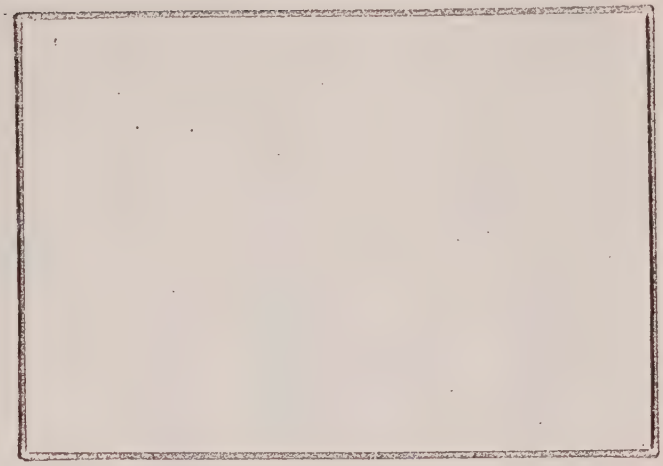
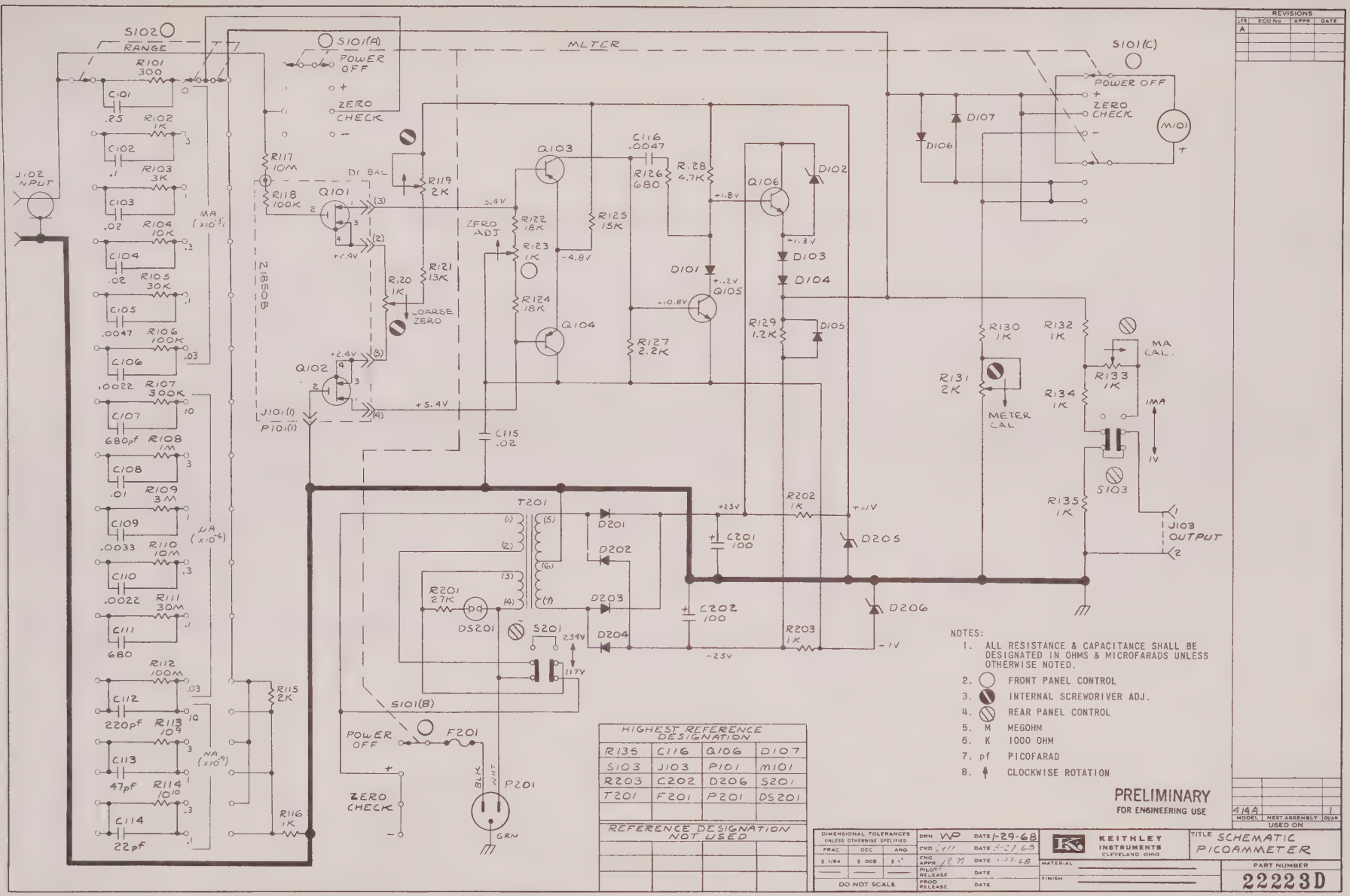


FIGURE 4. Divider Circuits Across Picoammeter Output for Driving 50 and 100-Millivolt Recorders. Use 5% resistors in the dividers. The value of resistor R is one ohm for every 1 mv of output.

d. 1-Milliampere Output. Connect 1-milliampere instruments to the OUTPUT Receptacle. Pin no. 1 is the high terminal. Set the 1 MA - 1 V Switch to 1 MA. The output is approximately 1 milliampere for full-scale meter deflection on any range. For exact output, apply a known full scale signal to the Picoammeter and adjust the 1 MA CAL Control until the recorder reads full scale. Check the recorder and meter zero and repeat adjustment if necessary. The METER Switch does not reverse the output polarity which is always opposite input polarity.

e. For servo rebalance recorders, use a divider across the Picoammeter OUTPUT Receptacle. See Figure 4. Set the OUTPUT Switch to 1 MA. Use the 1 MA CAL Control to trim the output for full-scale recorder deflection. Operation is the same as for current outputs.

2-6. 234-VOLT OPERATION. The instrument is shipped for use with a 117-volt power source unless otherwise ordered. To convert the Picoammeters for 234-volt sources, use a screwdriver to change the slide switch on the back panel to the 234-volt position. Change the fuse from 0.125 ampere to 0.62 ampere. No other adjustment is necessary. To switch from 234 to 117-volt operation, reverse the procedures.



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ◯ FRONT PANEL CONTROL
3. ⊘ INTERNAL SCREWDRIVER ADJ.
4. ⊘ REAR PANEL CONTROL
5. M MEGOHM
6. K 1000 OHM
7. pf PICOFARAD
8. ↻ CLOCKWISE ROTATION

PRELIMINARY
FOR ENGINEERING USE

HIGHEST REFERENCE DESIGNATION

R135	C116	Q106	D107
S103	J103	P101	M101
R203	C202	D206	S201
T201	F201	P201	DS201

REFERENCE DESIGNATION NOT USED

REVISIONS

LTR	ECO No.	APPR	DATE
A			

4194 MODEL | NEXT ASSEMBLY | QUAN
USED ON

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
FRAC ± 1/64 | DEC ± .005 | ANG ± 1°
DO NOT SCALE

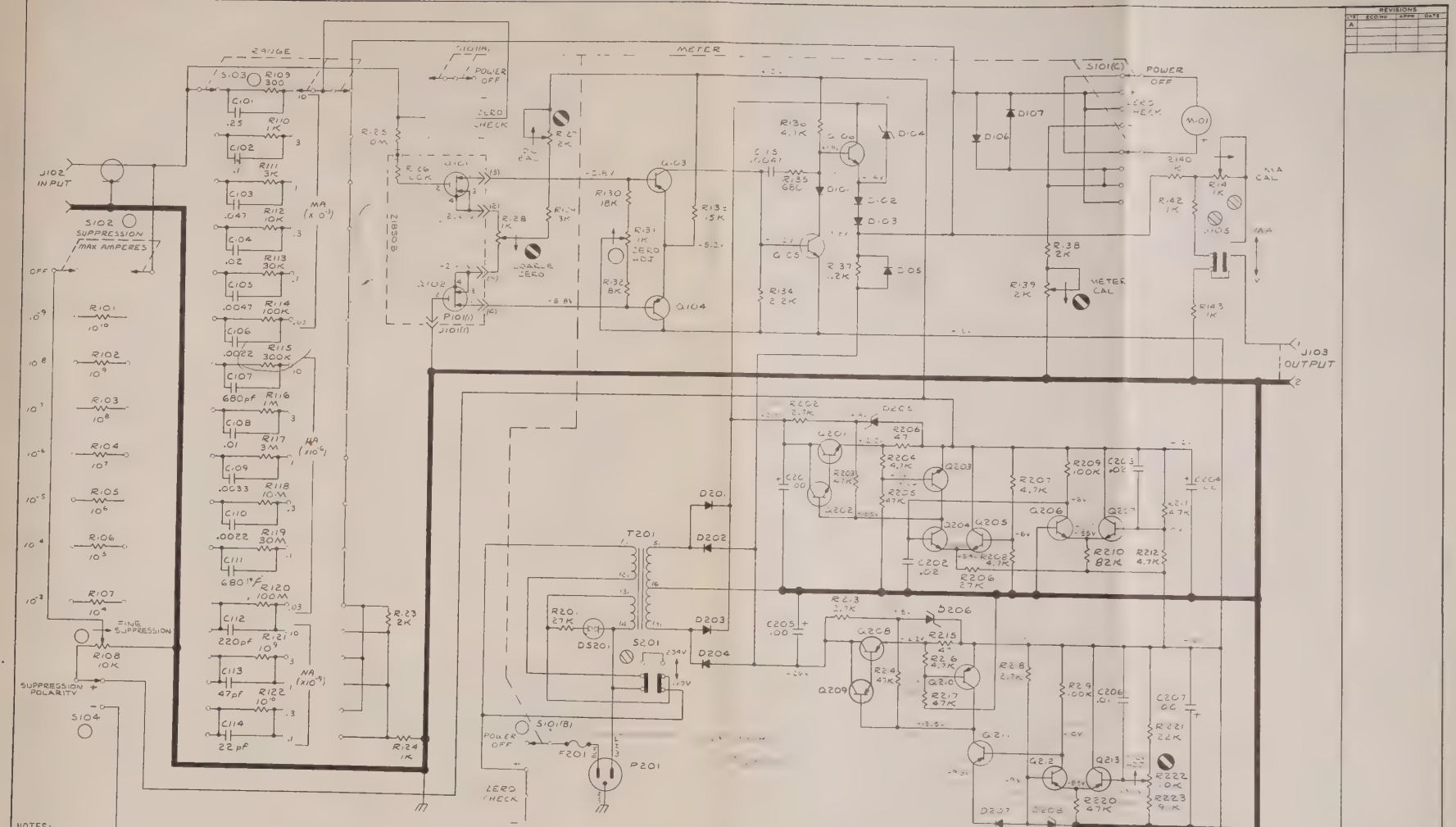
DRN WP DATE 1-29-68
CKD [illegible] DATE 2-21-68
ENG APPR [illegible] DATE 1-27-68
PILOT RELEASE DATE
PROD RELEASE DATE

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC PICOAMMETER

MATERIAL
FINISH

PART NUMBER 22223D



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3. ⊘ INTERNAL SCREWDRIVER ADJ.
4. ⊘ REAR PANEL CONTROL
5. M MEGOHM
6. K 1000 OHM
7. pf PICOFARAD
8. ↻ CLOCKWISE ROTATION

HIGHEST REFERENCE DESIGNATION			
R143	C115	D 07	Q C6
S105	J103	M-0	C222
C207	D208	Q2 3	S2C
T20.	D520.	F201	P201

REFERENCE DESIGNATION

PRELIMINARY
FOR ENGINEERING USE

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC PICOAMMETER

PART NUMBER 22394E

USED ON

MODEL NEXT ASSEMBLY USED ON

REVISIONS

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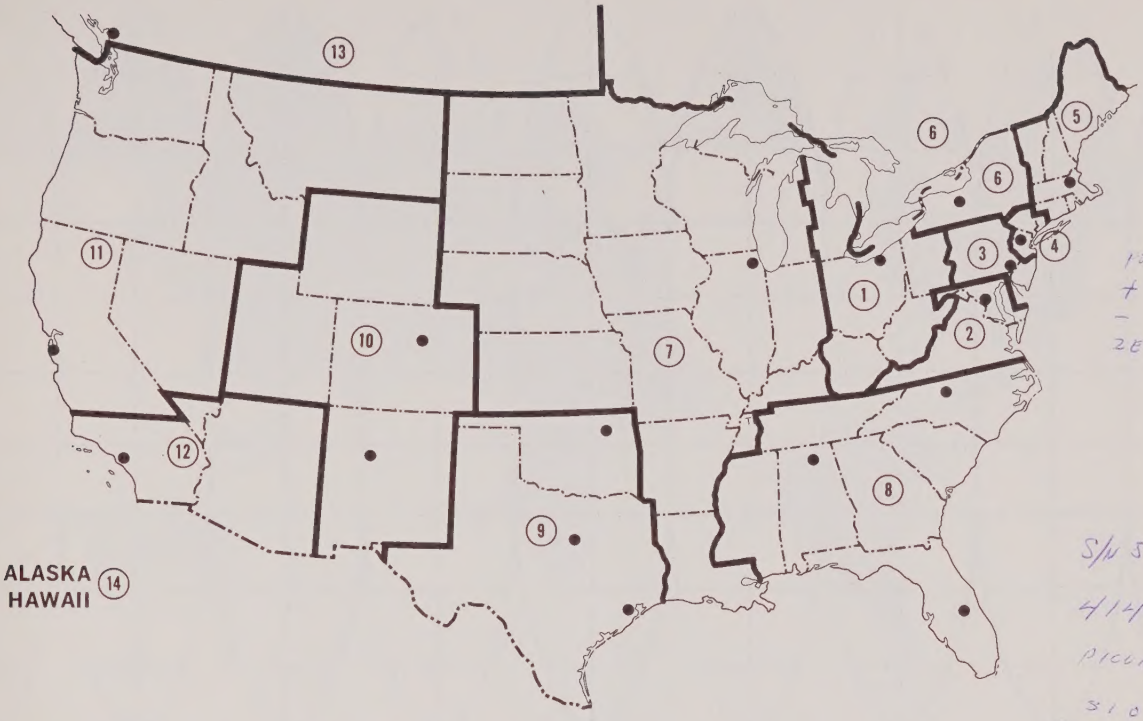

POWER OFF
+
–
ZERO

S/N 59466
414S
PICOAMMETER
3101
SWITCH

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14 NO REPRESENTATIVE
(See 1)

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european services

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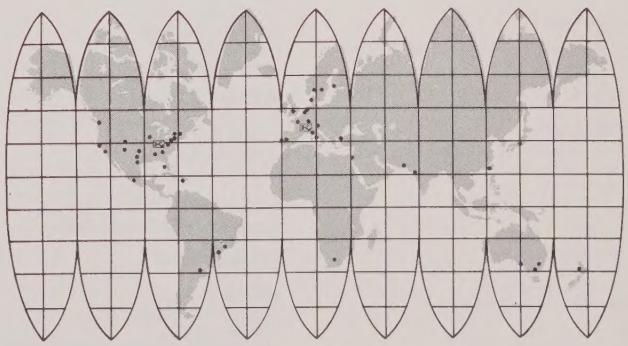

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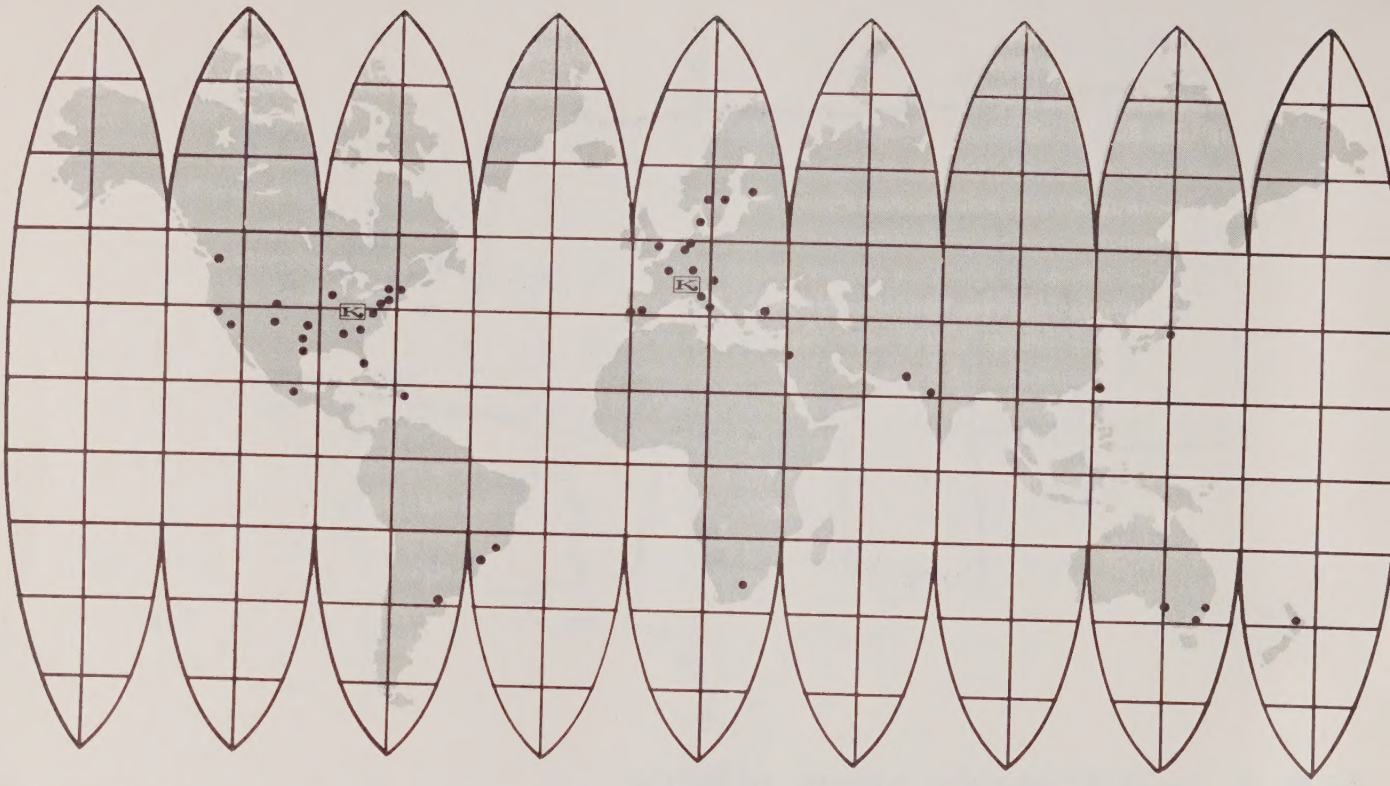

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